NASA/TM—2006-214449

Cool and Quiet

Partnering to Enhance the Aerodynamic and Acoustic Performance of Installed Electronics Cooling Fans: A White Paper

L. Danielle Koch and Dale E. Van Zante
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August 2006

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Space Administration

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Breathtaking images of distant planets. Spacewalks to repair a telescope in orbit. Footprints on the moon. The awesome is made possible by the mundane. Every achievement in space exploration has relied on solid, methodical advances in engineering.

Space exploration fuels economic development like no other endeavor can. But which advances will make their way into our homes and businesses? And how long will it take? Answers to these questions are dependent upon industrial involvement in government sponsored research initiatives, market demands, and timing.

Recognizing an opportunity is half the battle. This proposal describes the framework for a collaborative research program aimed at improving the aerodynamic and acoustic performance of electronics cooling fans. At its best, the program would involve NASA and academic researchers, as well as corporate researchers representing the Information Technology (IT) and fan manufacturing industries. The momentum of space exploration, the expertise resultant from the nation's substantial investment in turbofan noise reduction research, and the competitiveness of the IT industry are intended to be catalysts of innovation.

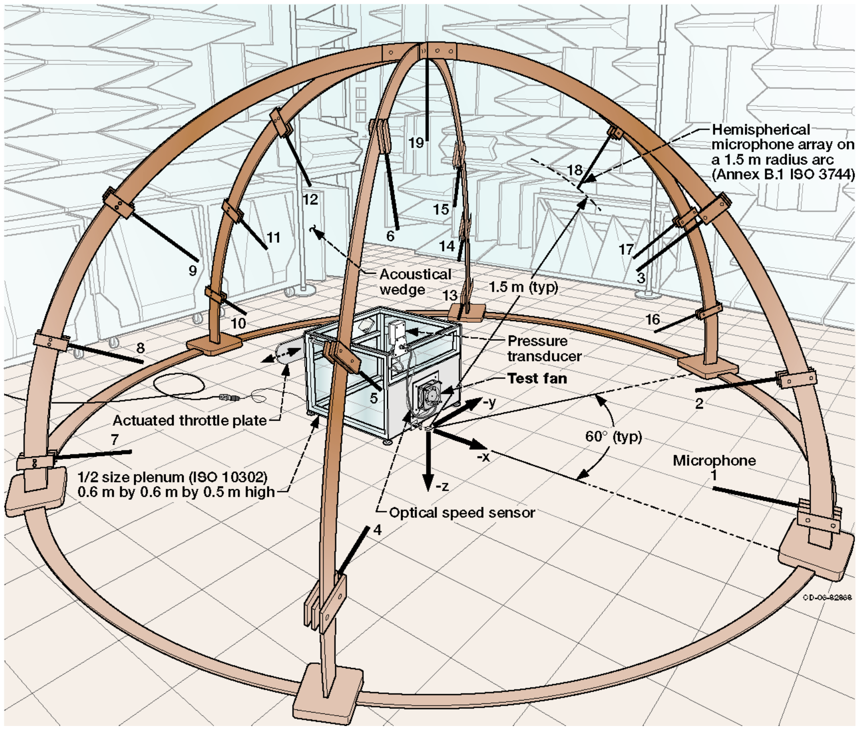
Can aircraft engine noise reduction technology be extended to improve cooling fan performance?

Objectives

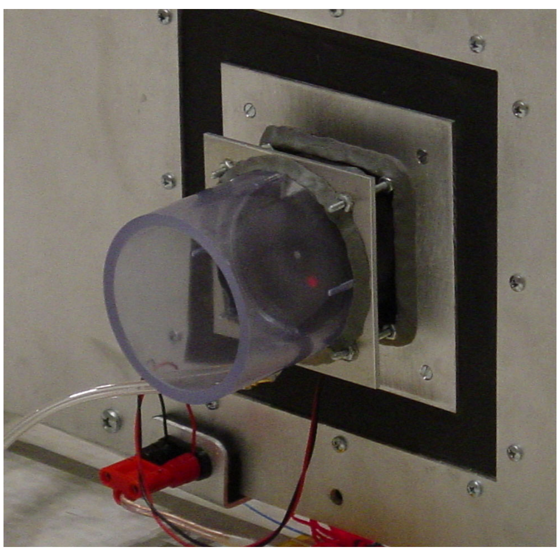
Cooling electronics quietly is easier said than done. When a low noise product is a goal, system designers ought to have the best aerodynamic and acoustic performance data in hand at the beginning of the design process. Often, though, designers must fend for themselves—either basing conceptual designs on limited data from fan manufacturers, or are saddled with the task of bench testing fans themselves to find the right fan installation that will allow the whole system to meet stringent noise limits.

The first goal of the partnership is to provide spaceflight hardware designers with measurements of the overall aerodynamic and acoustic performance for a set of cooling fans. Fans will be tested from free delivery to completely blocked conditions. And since system designers often have little choice but to install fans close to other package hardware, aerodynamic and acoustic performance maps will also be created for a set of inlet and exhaust obstructions and ducts. Since all fans would be tested for a uniform set of conditions, using standardized test procedures, in a single facility, impartial results would allow spaceflight hardware designers to make smart apples-to-apples comparisons.

As helpful as this information can be, some system designers will still be faced with tough compromises if existing fans do not perform as well as desired. The second goal of the partnership is to develop design and analysis capabilities that cooling fan manufacturers can use to improve the aerodynamic and acoustic performance of cooling fans.



The Acoustical Testing Laboratory at NASA Glenn Research Center



Understanding and eventually predicting how noise emissions can change when a fan is installed in a system can help prevent surprises at the end of a product design cycle. Test data for fans with ducted and obstructed inlets and exhausts can form a solid base for noise reduction research

How can this be done? NASA researchers can lead the way down a familiar path. First, additional detailed acoustic and aerodynamic data will be recorded and used in two ways—to extend models in existing fan noise codes developed for aircraft engine noise reduction and to validate this software for the cooling fan flow regime. Next, NASA would pursue the design and testing of a pair of fans. The baseline NASA fan would incorporate features designed to improve aerodynamic performance, and the second fan would include features intended to reduce noise without sacrificing aerodynamic efficiency.

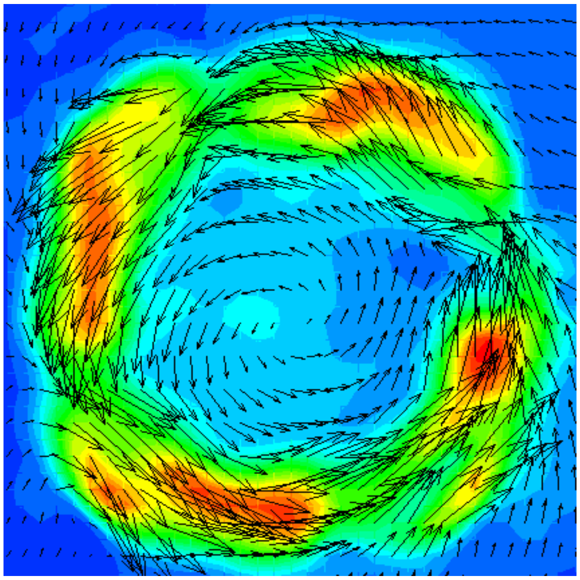
NASA's work is intended to be shared—so the NASA-owned fan geometry, test data accompanied by extensive interpretation, and validated noise prediction source code will be publicly distributed. Involving industrial partners in this research from the beginning can focus attention on common technical problems, foster new innovation, leverage research funding, and minimize time on the learning curve.

Methods

To accommodate the varied interests of potential consortium partners, the research has been segregated into four categories: verification tests, validation tests, aerodynamic and acoustic modeling and prediction, and NASA fan design and testing work.

Fan Performance Verification Tests

Fans considered for spaceflight could be tested in NASA Glenn's Acoustical Testing Laboratory (http://acousticaltest.grc.nasa.gov). Mounted on an automated fan plenum, each fan candidate would be throttled be created, both for fans with and without a set of inlet and exhaust obstructions, per ISO10302 and ISO3744. As an from free flow conditions to completely blocked. Maps of the overall aerodynamic and acoustic performance[1,2] would incentive to



Seeing the invisible: Particle Image Velocimetry can be used to measure the magnitude and direction of the flow exiting a cooling fan. Maps like this can give indications of how well the fan is performing aerodynamically and can be used to help identify the sources of noise.

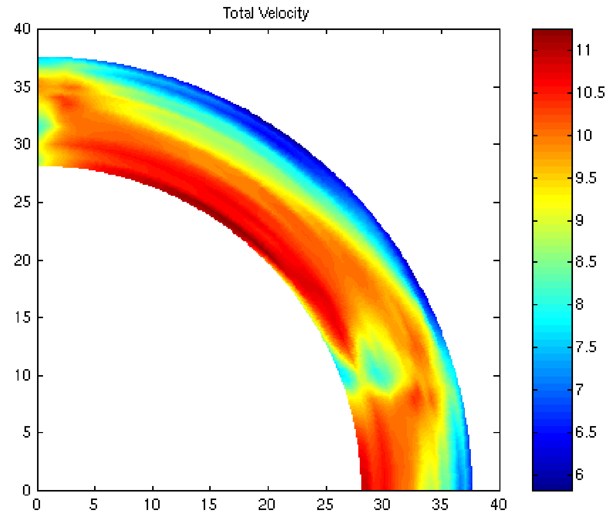
participate in this study, IT and fan manufacturing industrial partners capable of providing fan geometry and fan design point conditions would be invited to provide NASA with a fan of their choice for inclusion in the Performance Verification Tests (IT fans will not need to meet requirements for spaceflight). Results from the test will be appropriately non-dimensionalized in publicly distributed reports, and proprietary information will be protected.

Acoustic and Aerodynamic Validation Tests

Upon examination of the results of the Fan Performance Verification Tests, a subset of fans would be selected as subjects for the Acoustic and Aerodynamic Validation Tests. The subset should adequately represent the larger group, and ideally, would include one fan per industrial partner. This detailed data would be used for code modeling and validation, and will be instrumental in the design of the NASA fans.

For the Acoustical Validation Tests, the fans could once again be mounted on the automated fan plenum within the Acoustical Testing Laboratory at NASA Glenn. Testing similar to that reported by Washburn and Lauchle[3] would be conducted. A set of microphones would be mounted to a 180° arc spanning from the fan inlet to the exhaust and spectra would be measured and synchronously averaged. Data would be collected for a number of fan flow rates and inlet/exit conditions.

Two types of Aerodynamic Validation Tests would be required for each fan, and the facilities and instrumentation needed for each type are currently available at NASA Glenn.[1,2] First, 2D and 3D Particle Image Velocimetry (PIV) would be



Accurately modeling realistic fan wakes is just one part of creating the next generation of fan noise prediction tools. Hot wire measurements, such as these shown here, can be used to validate fan tone noise prediction software.

used to fully characterize the inlet and exhaust regions of the fan. Second, hot wire probes would be used to measure the fan blade wakes inside the shroud. Again, these measurements would be taken for a number of fan flow rates, with and without obstructions at the fan inlet and exit.

Acoustic Modeling and Prediction

The acoustic and aerodynamic data would be used to extend existing fan noise codes and validate them for the cooling fan regime. Once this work is completed, noise predictions for each of the fans participating in the validation tests would be generated. In addition, a parametric design study would be conducted in order to generate requirements for the second NASA fan.

NASA Fan Design and Testing

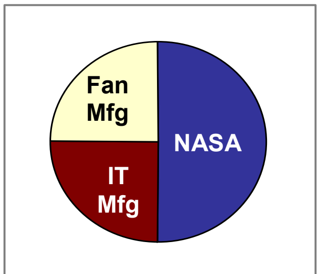
A pair of NASA-owned fans would be designed: the baseline fan, again, incorporating features to improve the aerodynamic performance, and the second a variation to reduce fan tone noise without sacrificing aerodynamic performance. The fan geometries and general design guidelines would be documented and publicly distributed.

Each industrial partner would be expected to fabricate the pair of NASA fans. Since the aerodynamic design would be common, performance differences due to fabrication and motor selection could be studied. The entire set of NASA fans (one pair per industrial partner) would be subjected to the Performance Verification Tests, and a subset would go on for further Acoustic and Aerodynamic Validation Tests. Computational fluid dynamics (CFD) predictions for the NASA fans (with and without obstructions), as well as predicted noise, would be compared against the validation data in publicly distributed documents.

Partner Contributions

Costs of the research described here are expected to be shared between NASA and the participating industrial partners. Funds should be allocated according to the primary interests of the partners.

Most interested in the measurement of the overall performance for a set of fans, funding from the NASA Explorations Systems Mission Directorate (ESMD) is sought for the Performance Verification Tests. Since the prediction of noise produced by an obstructed fan is of interest to both the cooling fan and aircraft engine industry, funding is also sought from the NASA Aeronautics Research Directorate (ARMD) for the Acoustic Modeling and Prediction work. The industrial partners would benefit most from the validated design and analysis tools that could be used to improve commercial products. As such, funding is sought from each industrial partner to cover the costs of the Acoustic and Aerodynamic Validation Tests. The cost of the design, analysis, and testing of the NASA fans should be shared by NASA and the corporate partners.



Cost Sharing Structure

Proposed Fund Allocation	
Fan Performance Verification Tests	NASA ESMD Human System Research and Technology Development Program
Acoustic and Aerodynamic Validation Tests	Industrial Partners
Acoustic Modeling and Prediction	NASA ARMD Subsonic Fixed Wing Program
NASA Fan Design and Testing	50% NASA ESMD 50% Industrial Partners

Literature supports the view that cooling fan performance could benefit from technology already developed for aeropropulsion.[4] Working individually, it is possible to change a product. Working collaboratively, it is possible to change an industry.

References

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2. “An assessment of NASA Glenn’s aeroacoustic experimental and predictive capabilities for installed cooling fans: Part 2: Source identification and validation,” Koch, Van Zante, Wernet, Podboy, NASA/TM—2006-214450.
3. “Effects of inflow conditions on discrete frequency noise generated by small, axial flow fans,” Washburn and Lauchle. ARL–TR–85–001.
4. “Fan Technology: Evolutionary Potential and Evolutionary Limits,” http://www.triz-journal.com /archives/2004/12/04.pdf.

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Breathtaking images of distant planets. Spacewalks to repair a telescope in orbit. Footprints on the moon. The awesome is made possible by the mundane. Every achievement in space exploration has relied on solid, methodical advances in engineering. Space exploration fuels economic development like no other endeavor can. But which advances will make their way into our homes and businesses? And how long will it take? Answers to these questions are dependent upon industrial involvement in government sponsored research initiatives, market demands, and timing. Recognizing an opportunity is half the battle. This proposal describes the framework for a collaborative research program aimed at improving the aerodynamic and acoustic performance of electronics cooling fans. At its best, the program would involve NASA and academic researchers, as well as corporate researchers representing the Information Technology (IT) and fan manufacturing industries. The momentum of space exploration, the expertise resultant from the nation's substantial investment in turbofan noise reduction research, and the competitiveness of the IT industry are intended to be catalysts of innovation.

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